BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 09046

SUBJECT: Possible Sources of Seismic and Transient Events in the Fra Mauro Region - Case 340

DATE: September 18, 1970

FROM: J. W. Head

ABSTRACT

Recent analysis of results from the Apollo 12 Passive Seismic Experiment (PSE) by G. Latham has shown a remarkable correlation between certain characteristic seismic signals and the moon's perigee. Previously, a correlation had been suggested between tidal and gravity effects and increased sightings of lunar transient events. Study of the Apollo 12 seismic records produced by the perigee and near-perigee events led Latham to suggest that the characteristic signals may originate in the Fra Mauro crater area.

Several potential sources of lunar seismic and transient events exist in the vicinity of the Fra Mauro crater and the Apollo 14 landing site. These are of two principal types: those related to the extensive graben-like rille system, and those related to apparent constructional and blanketing volcanic deposits. The characteristics and location of these potential sources are outlined in the hope that the seismic signals noted by Latham during perigee can be correlated with transient events which might originate in the vicinity of the source of the signal. Based on the distribution of potential sources the suggestion is made that the Cold Cathode Gauge Experiment be oriented in a southerly or west to west-northwest direction during the Apollo 14 mission to the Fra Mauro region.

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MEMORANDUM FOR FILE

I. Introduction

Recent analysis of results from the Apollo 12 Passive Seismic Experiment (PSE) has shown a remarkable correlation between certain characteristic seismic signals and the moon's perigee.(1) Previously, a correlation had been suggested between tidal and gravity effects and possible intensification of lunar defluidization and volcanism.(2) Analysis of over 400 lunar events indicated a correlation of these events with lunar tides and suggested that the onset of a lunar event may be associated with disturbance of the lunar crust.(3) Study of the Apollo 12 seismic records produced by the perigee and near-perigee events suggest that the characteristic signals may originate in the Fra Mauro crater area, and the PSE Principal Investigator, Dr. Gary Latham, has postulated that the seismic activity at perigee may trigger lunar events in this area. With the hope of correlating lunar transient events with seismic events in the Fra Mauro crater region, Latham recently requested an intensification of observation in this area at perigee, through the Smithsonian Astrophysical Observatory's Center for the Study of Short-Lived Phenomena.

The purpose of this paper is to outline the most likely areas in the Fra Mauro crater region where seismic events might occur and transient events might be sighted.

II. The Nature and Distribution of Lunar Transient Events

Transient events observed on the moon from earth commonly fall into several catagories:

1) color changes

2) obscurations of areas up to a few kilometers

3) bright spots on the dark portion of the moon

4) spectral bands

Middlehurst and Moore[4] have plotted the topographical distribution of some 400 reports of transient events and found that the sites fall into three classes:

1) sites peripheral to the maria

2) ray craters

3) ring plains with dark or partially dark floors

The reliability and lack of bias of the data analyzed by Middlehurst and Moore have been questioned[5,6]. Whatever the case for moon-wide distribution in the comprehensive references reviewed[3,4,7], no record of transient events in the Fra Mauro area could be found. This, of course, does not rule out the possibility of transient events occurring in this region.

III. Geologic Setting

The geologic setting and history of the Fra Mauro region is an important factor in determining possible sources of seismic and transient events. Geologic mapping of the Fra Mauro region by Eggleton[8] at a scale of 1:1,000,000 reveals the following sequence of events:

1) During a period of time (pre-Imbrian) prior to the origin of the Imbrium Basin, a number of large craters were formed, including Fra Mauro, Parry, Bonpland, and Guericke (Figure 1).

2) The event which produced the Imbrium Basin deposited a thick regional mantle of material as an ejecta blanket around Mare Imbrium. This unit, which filled and subdued many large craters, is known as the Fra Mauro Formation. Deposition of the Fra Mauro Formation defines the base of the Imbrian System.

3) A series of linear rilles trending in a general north-south direction appear to be part of the next phase of the history of this area. Several of these rilles cut pre-Imbrian craters such as Bonpland and Parry as well as the Fra Mauro Formation itself. The straight rilles are dominantly graben-like features.

4) An era of mare basin and lowland flooding characterizes subsequent history in the region. In addition to the general mare flooding, the craters Fra Mauro and Bonpland were partially flooded, sometimes obscuring parts of the linear rilles.

5) Continued cratering occurred up to the present time (e.g., Parry A, Parry F), modifying the topography produced by the earlier geologic history. In addition, several volcanic-like structures associated with dark mantling material are present in the vicinity and may post-date the period of mare basin fill.

The two features in this region most likely to be responsible for seismic and transient events are 1) the graben-like straight rilles which might show movement during periods of global lunar stresses, and 2) the apparent volcanic areas associated with dark mantling material which might be centers for various emanations responsible for transient events. Indeed, Hartmann and Harris[9] have recently correlated certain transient events around the rim of Aristarchus with certain volcanic-appearing flow-like structures superimposed on the crater rim deposits.

IV. Linear Rilles

Prominant linear rilles in the region of the Fra Mauro crater are shown in Figure 1. The majority of the rilles appear to be graben-like fault bounded troughs. The lack of deflection of the surface trace of the faults when topographic prominences are crossed (e.g., the south wall of Fra Mauro) indicates that the dip of the faults is essentially vertical. The majority of the north-south trending linear rilles are part of a system of fractures radial to the Imbrium Basin and may have originated in association with that basin.[10,11] There is no conclusive evidence for major movement associated with these faults in this area in the period following mare basin flooding. However, since these are dip-slip instead of strike slip faults, movement is difficult to document. Rocks from the Apollo 12 site in eastern Oceanus Procellarum have been dated at 3.26-3.36 billion years[12]. This age probably represents the time of cooling of surface lava flows at this site, some 200 km to the WNW of Fra Mauro crater. If the dark mare material which embays several linear rilles (Bonpland, Fra Mauro) is of similar age, much of the faulting must have taken place prior to this time. However, in other areas of Fra Mauro and Bonpland, linear rilles transect dark mare material. The major north-south linear rille, Rima Parry I, has craters superimposed on it (Parry A and Parry F) which have been dated as Imbrian in age[8].

Finally, dark blanketing materials cover a large portion of Rima Parry V at the southern rim of Fra Mauro while this same rille appears to cut dark mare material some 15km further south in the crater Bonpland. This implies that there was tectonic movement during deposition of the dark mare material and that apparent volcanic activity persisted after the completion of major movement along Rima Parry V.

The most likely rille regions for tidally-induced seismic and transient phenomena are:

1) Rima Parry V (Figure 2): It is not completely clear that this segment of the rille (just at the north rim of Bonpland) cuts the dark material since the dark material may be so thin that it covers the rille without subduing it.

2) Rima Parry I: Although parts of this rille can be shown to be relatively old, its sheer magnitude suggests that it might be a likely source for tidally-induced seismic and transient phenomena.

V. Regions of Apparent Volcanic Activity

Numerous dark blanketing deposits overlie various portions of the rille system. Localized centers of this relatively younger volcanic activity could also provide a source of seismic and transient phenomena.

Three of the most likely centers of volcanic activity are shown in Figure 2. The most interesting example is located in the southern part of Fra Mauro near where Rima Parry V crosses the crater wall. In this area, Rima Parry V is blanketed and totally obscured for a distance of 9 km by relatively dark material associated with a linear row of cratered hills and cones which parallel the trace of the rille (Figures 2, 3). Many of these hills have summit craters and they appear to be volcanic constructional forms. Figure 3 illustrates the nature of these features and shows their relation to the rille and the dark blanketing material. Since this area covers a segment of Rima Parry V and appears relatively fresh, it represents one of the most likely areas in this region for possible sources of transient pheonomena.

A second apparent volcanic area is very similar to, but less extensive than the row of cratered hills and cones just described. This structure (Figure 2) is located at the north rim of Bonpland just east of Rima Parry V and 14 km south of the similar more extensive set of hills. It may also be the source of some dark mantling material such as that seen in the northern part of Bonpland.

The third area is also associated with this dark material in the north part of Bonpland. It is characterized by a roughly triangular shaped crater (Figure 2) which may be a volcanic vent and a possible source of some of the dark material in this region. This crater could also be a source of transient phenomena and seismic activity.

Finally, Eggleton[13] has mapped a series of domical hills, and materials associated with a sinuous scarp, in an area to the west and northwest of the crater Fra Mauro (Figure 1). The domical hills are probable volcanoes possibly represented by pyroclastic cones and viscous flow domes. Most of these structures are superimposed on top of material of Imbrian age and several are covered by ejecta probably from the crater Copernicus. These structures may also be sources of seismic events and transient phenomena. The general location of those mapped by Eggleton is shown in Figure 1. The distribution of domes and cones shown in Figure 1 is confined to the area mapped by Eggleton (points in that area are within 65 km of the Apollo 14 landing site). However, there appears to be a definite asymmetry of distribution in Figure 1, with a considerably greater number of these features in the western part of Figure 1 than in the eastern. In particular, a large number are present to the southwest of the area of domes and cones mapped by Eggleton.

The materials associated with sinuous scarps are located in the same general area and are interpreted to be lavas or pyroclastic material erupted along faults.[13] These deposits are judged by Eggleton to be Copernican in age. Their location is also shown in Figure 1 and they could also be a source for seismic or transient events.

VI. Application to the Apollo 14 Mission to the Fra Mauro Region

Deployment of the Cold Cathode Gauge Experiment (CCGE) as part of the Apollo 14 ALSEP raises the possibility of an additional, non-seismic method of detection of lunar transient events in the Fra Mauro region. Chang and Yeh[14] have considered this possibility and their results suggest that a gas release rate of at least 2 gm/sec is required at a source located 100 km away in order to be detected by the CCGE. This is encouraging since, assuming a volcanic source, Kozyrev[15] calculated a gas release rate of about 10^5 gm/sec for his 1958 obeservations of Alphonsus.

Based on the characteristics and distribution of potential transient event sources the following suggestions are advanced:

1) The CCGE should be oriented in a southerly direction on Apollo 14 since the most likely transient event source region is the concentration of linear rilles approximately due south of the Apollo 14 landing site (Figure 1). Similarly, three of the volcanic areas also lie essentially due south. The locus of these features (around the common rim of Fra Mauro, Bonpland, and Parry) lies slightly more than 100 km south of the Apollo 14 site.

2) The area of cones and scarp-associated material represents a second possible source of transient events in an area 30-45 km west and west-northwest of the Apollo 14 landing site. Orientation of the CCGE towards this region may be preferable if other distances prove too great for detection of if operational considerations preclude orientation in a southerly direction.

VII. Conclusions

Several potential sources of lunar seismic and transient events exist in the vicinity of the Fra Mauro crater and the Apollo 14 landing site. These are of two principal types: those related to the extensive graben-like rille system, and those related to apparent constructional and blanketing volcanic deposits. The characteristics and location of these potential sources are outlined in the hope that the seismic signals noted by Latham during perigee[1] can be correlated with transient events emanating from the vicinity of the source of the signal. Based on the distribution of potential sources the suggestion is made that the CCGE be oriented in a southerly or west to west-northwest direction during the Apollo 14 mission to the Fra Mauro region.

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Attachments
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Figures 1-3

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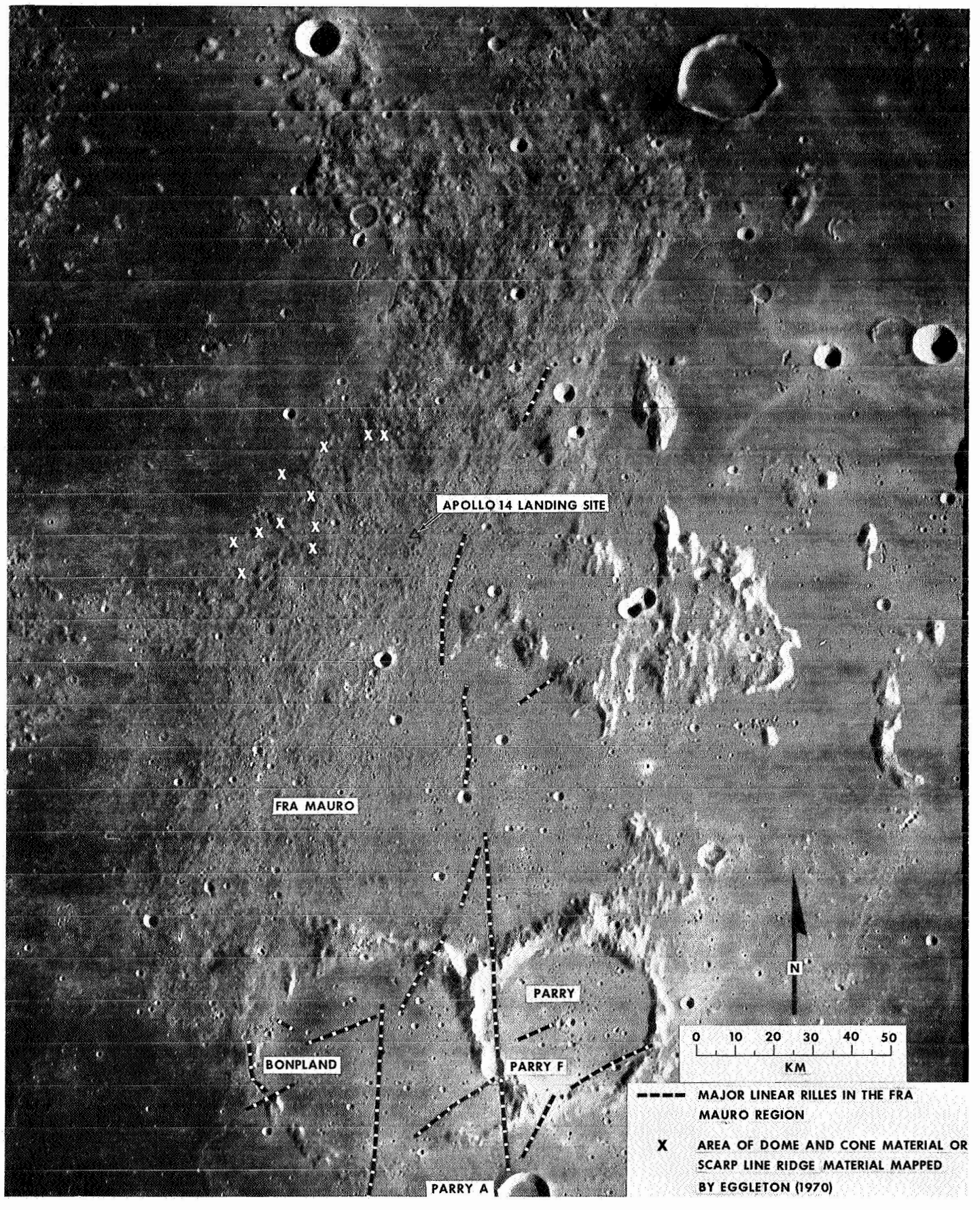

FIGURE 1 - MAJOR LINEAR RILLES IN THE FRA MAURO REGION, LUNAR ORBITER IV FRAME 120 H.

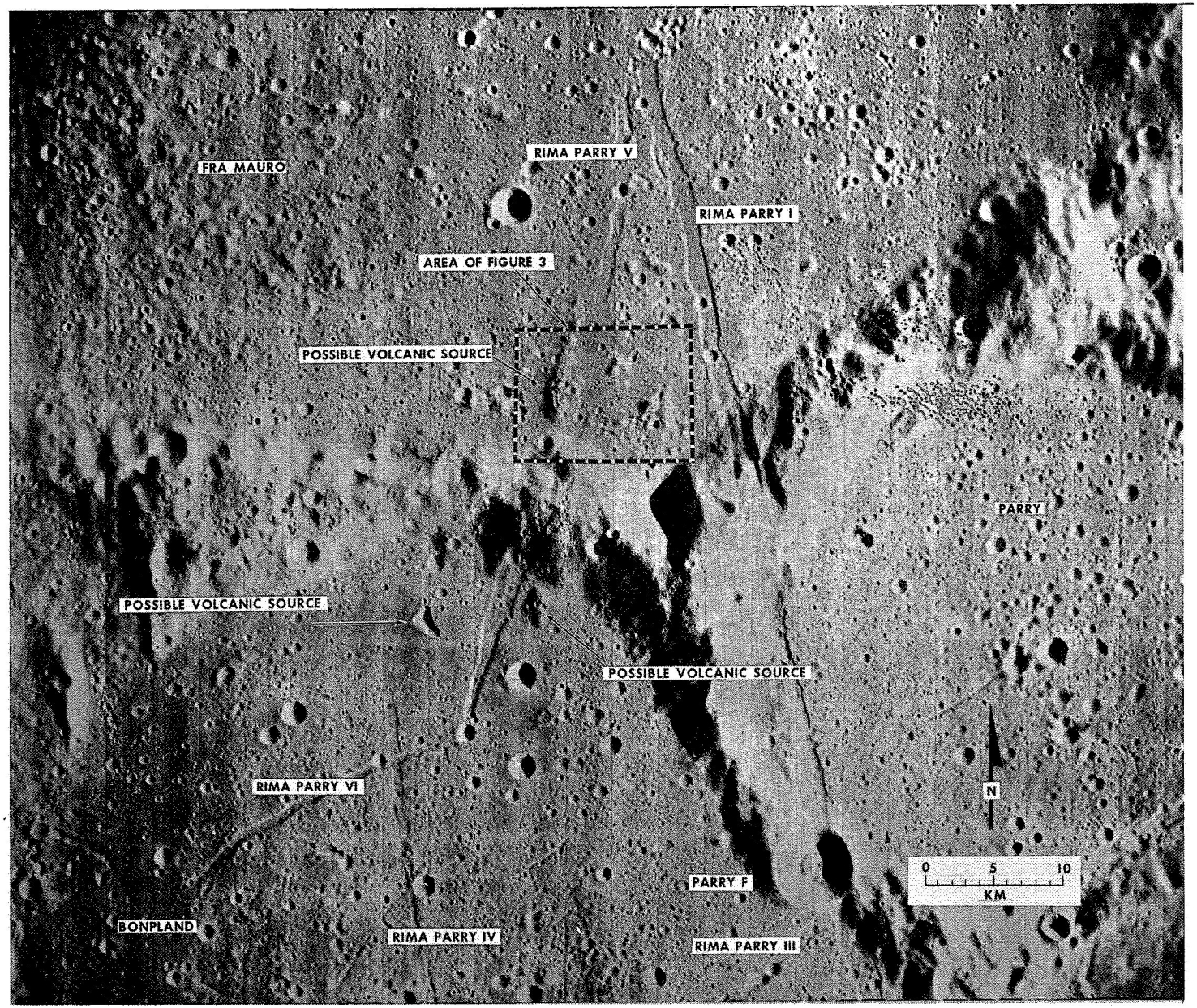

FIGURE 2 - LINEAR RILLES AND POSSIBLE VOLCANIC AREAS, SOUTHERN FRA MAURO REGION. LUNAR ORBITER V FRAME 138 M.

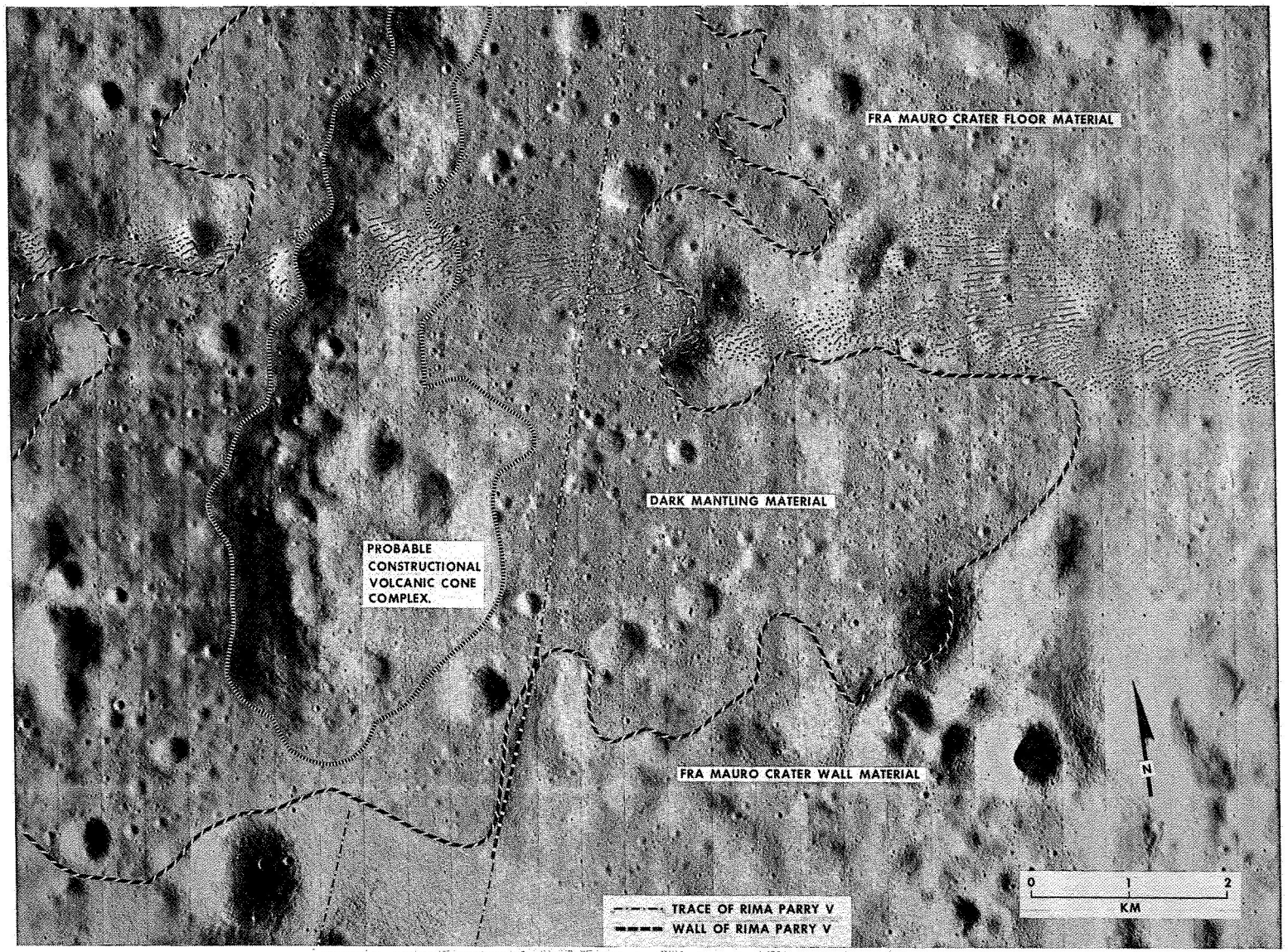

FIGURE 3 - PROBABLE VOLCANIC CONSTRUCTIONAL DEPOSITS AND ASSOCIATED DARK MATERIAL OBSCURING RIMA PARRY V. FOR LOCATION, SEE FIGURE 2. LUNAR ORBITER V FRAME 139 H.